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Combined nanoimprint and photolithography of integrated polymer optics

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We demonstrate wafer-scale fabrication by combined nanoimprint and photolithography (CNP) [1] of integrated polymer optics, combining active and passive polymer components with nm to mm features. Distributed feed-back (DFB) polymer dye lasers [2] are integrated with polymer waveguides [3]. The laser devices are defined in SU-8 resist, doped with Rhodamine 6G laser dye, shaped as planar slab waveguides on a Fused Silica buffer substrate, and with a 1st-order DFB surface corrugation forming the laser resonator, see Fig. 1. When optically pumped at 532 nm, lasing is obtained in the wavelength range 560 nm – 600 nm, determined by the grating period, see Fig. 3. Our results, where 20 laser devices are defined across a 10 cm diameter wafer substrate, demonstrate the feasibility of CNP for wafer-scale fabrication of advanced nano-structured active and passive polymer optical components

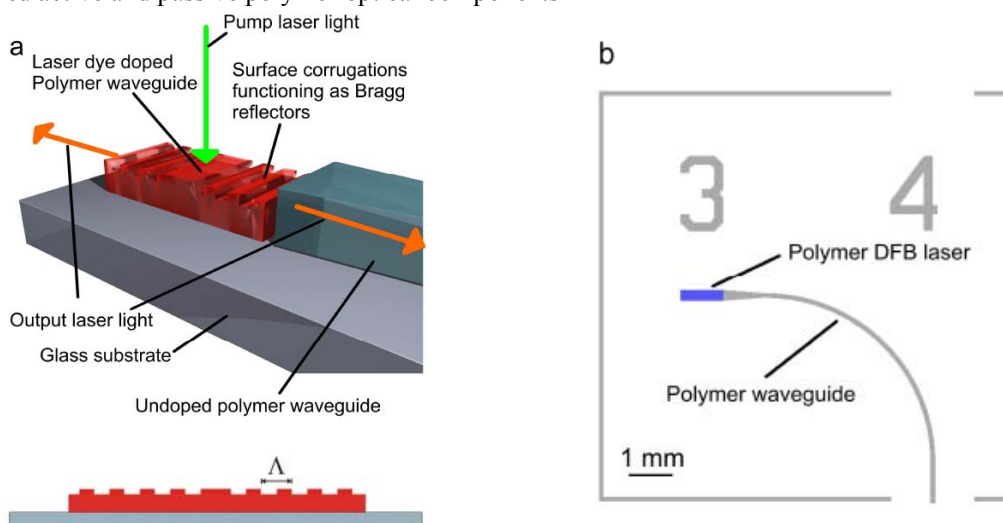


Fig. 1 (a): Outline of the distributed feed-back (DFB) polymer dye laser device, formed as a slab waveguide on a borofloat glass substrate. Feedback is provided by Bragg grating surface corrugations of period $\Lambda \sim 200$ nm. (c) The chip layout. The laser is positioned 10 μm from a curved waveguide made of 4.2 μm thick undoped SU-8 polymer. 20 chips are defined across the 10 cm diameter wafer substrate.

In the CNP process, a combined UV mask and nanoimprint stamp, Fig 2 (a)-(b), is embossed into the resist, which is softened by heating, and UV exposed, Fig 2 (c)-(d). Hereby the mm to μm sized features are defined by the UV exposure through the metal mask, while nm-scale features are formed by mechanical deformation (nanoimprinting). The UV exposed (and imprinted) SU-8 is crosslinked by a post-exposure bake, before the stamp and substrate are separated, and the un-exposed resist is dissolved, Fig 2 (e). Polymer waveguides are added [3] by an additional UV lithography step in a film of un-doped SU-8, which is spincoated on top of the lasers and substrate, Fig. 2 (f)-(g).

The combined UV mask and nanoimprint stamp is fabricated from a 10 cm diameter, 500 μm thick Quartz wafer. To define the sub-micron features ($\Lambda \sim 200$ nm period Bragg gratings), the Quartz wafer is spin-coated with a 50 nm thick film of TEBN-1 electron beam lithography (EBL) resist, and a 20 nm aluminium film is deposited to avoid charging effects during the EBL exposure. Following the 100 kV EBL exposure, the charge compensating layer is removed in MF-322 and the TEBN-1 resist is developed in methyl isobutyl ketone (MIBK). A RIE process transfers the gratings 40 nm into the substrate. The UVL mask - 200 nm Cr

and 20 nm aluminium - is defined by UV lithography and lift-off. Before metal deposition, the un-masked areas are recess-etched by RIE (250 nm). Finally, an anti-stiction coating is deposited on the stamp. The Rhodamine 6G perchlorate doped SU-8 resist (13 wt% solid content SU-8 in cyclopentanone) is prepared as described in [3]. The final Rhodamine concentration is 3.2 μmol per g solid SU-8. The SU-8 is spincoated onto a borofloat glass substrate to a thickness of 450 nm. The combined UV mask and stamp is embossed into the unexposed SU-8 at 90°C and 2.5 bar before UV (i-line) exposure, and post-bake (2 min. 90°C). After separation the SU-8 is developed in PGMEA.

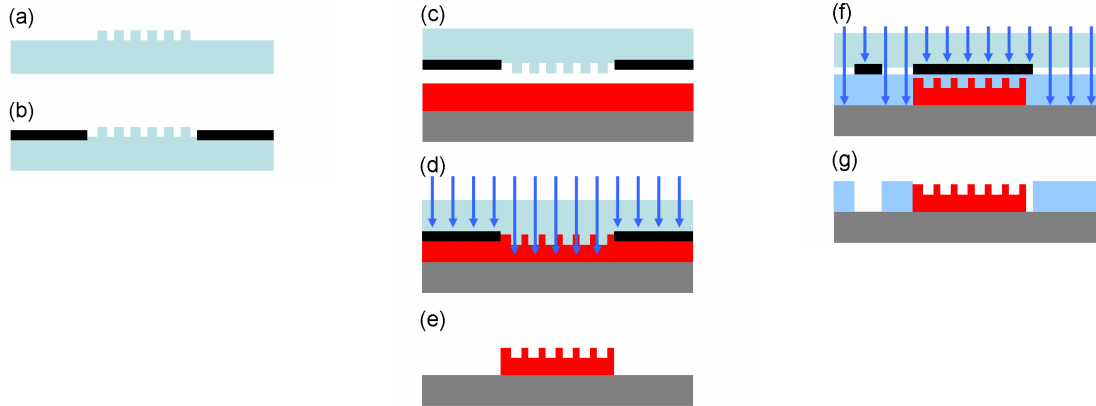


Fig. 2 Outline of the CNP fabrication process. (a)-(b): Combined UV mask and imprint stamp is used. (c)-(e): Embossing and UV exposure of dye doped resist to form DFB lasers. (f)-(g) Additional UV lithography step in undoped SU-8 film to define polymer waveguides.

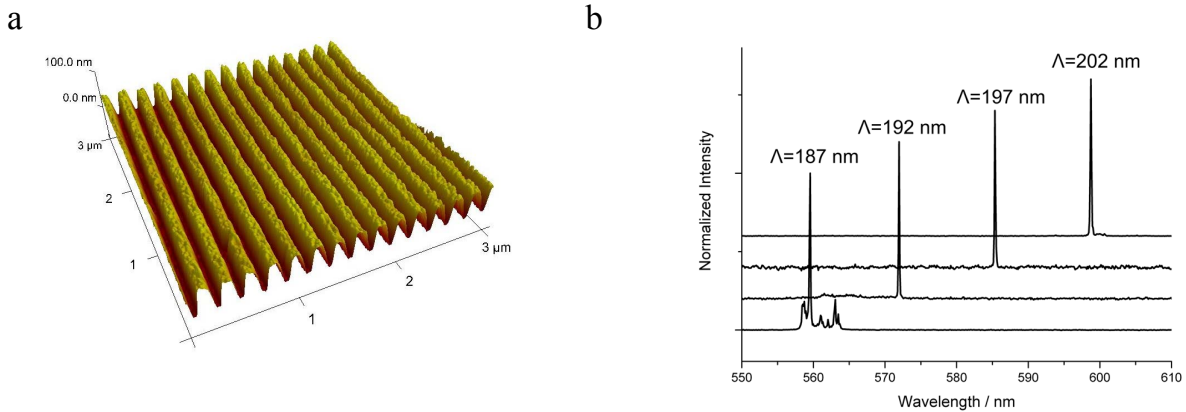


Fig. 3 (a) AFM image of a fabricated DFB surface corrugation. The period is $\Lambda = 188$ nm, and the corrugation depth is $a = 60$ nm. (b) Emission spectra from four laser devices of different DFB grating pitch.

Fig. 3a shows an AFM image of a CNP fabricated surface corrugation, forming the Bragg gratings. The period is $\Lambda = 188$ nm. This grating is expected to yield 1st order Bragg reflection at a vacuum wavelength of 577 nm. In Fig. 3b we show the emission spectra from four lasers of different DFB grating period Λ .

References:

- [1] X. Chen and L. Jay Guo, "One-step lithography for various size patterns with a hybrid mask-mold", *Microelectron. Eng.* 71, 288 (2004)
- [2] S. Balslev, T. Rasmussen, P. Shi, and A. Kristensen, "Single mode solid state distributed feedback dye laser fabricated by grey scale electron beam lithography on dye doped SU-8 resist", *J. Micromech. Microeng.*, Vol. 15, 2456 (2005)
- [3] D. Nilsson, S. Balslev, M. M. Gregersen, and A. Kristensen, "Micro-fabricated solid state dye lasers based on a photo-definable polymer", *Applied Optics*, Vol. 44, 4965 (2005)